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(12) UK Patent Application (19) GB (11) 2 037 554 A

(21) Application No 7849595
(22) Date of filing 21 Dec 1978
(43) Application published 16 Jul 1980
(51) INT CL³ A01G 7/00 7/02
(52) Domestic classification A1E 3
(56) Documents cited
GB 1479681
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GB 1349001
GB 1302613
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GB 1174452
GB 1164881
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GB 1032657
(58) Field of search A1E

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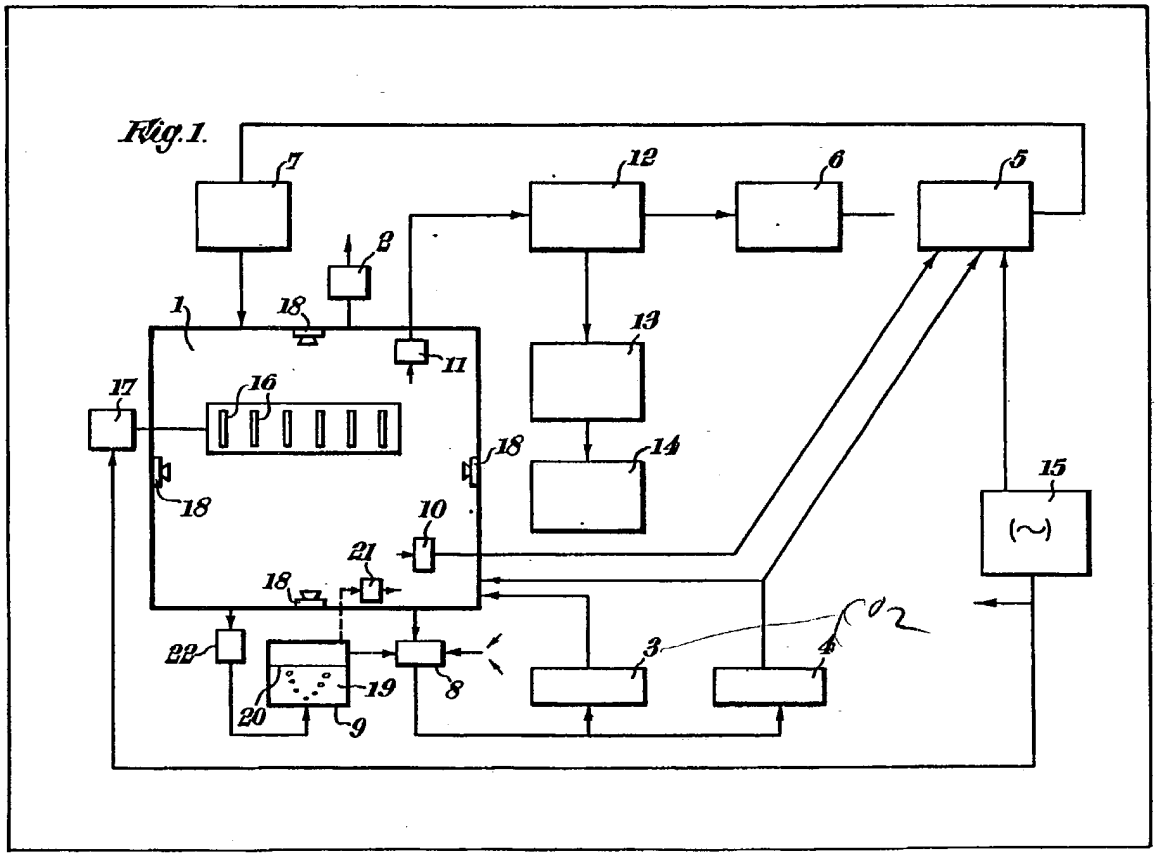
(54) Control of plant growing environment

(57) In order to provide a versatile system capable of optimum plant cultivation in a variety of situations for a variety of plants, an enclosure (1) in which plants or seeds are grown either has no ventilation to external atmosphere or has only ventilation via filtering means (2) to external atmosphere. The apparatus also includes carbon dioxide supply (3, 4), temperature and humidity control (10, 11, 12, 7) and lighting means (16, 17) controllable in respect of duration, intensity and colour.



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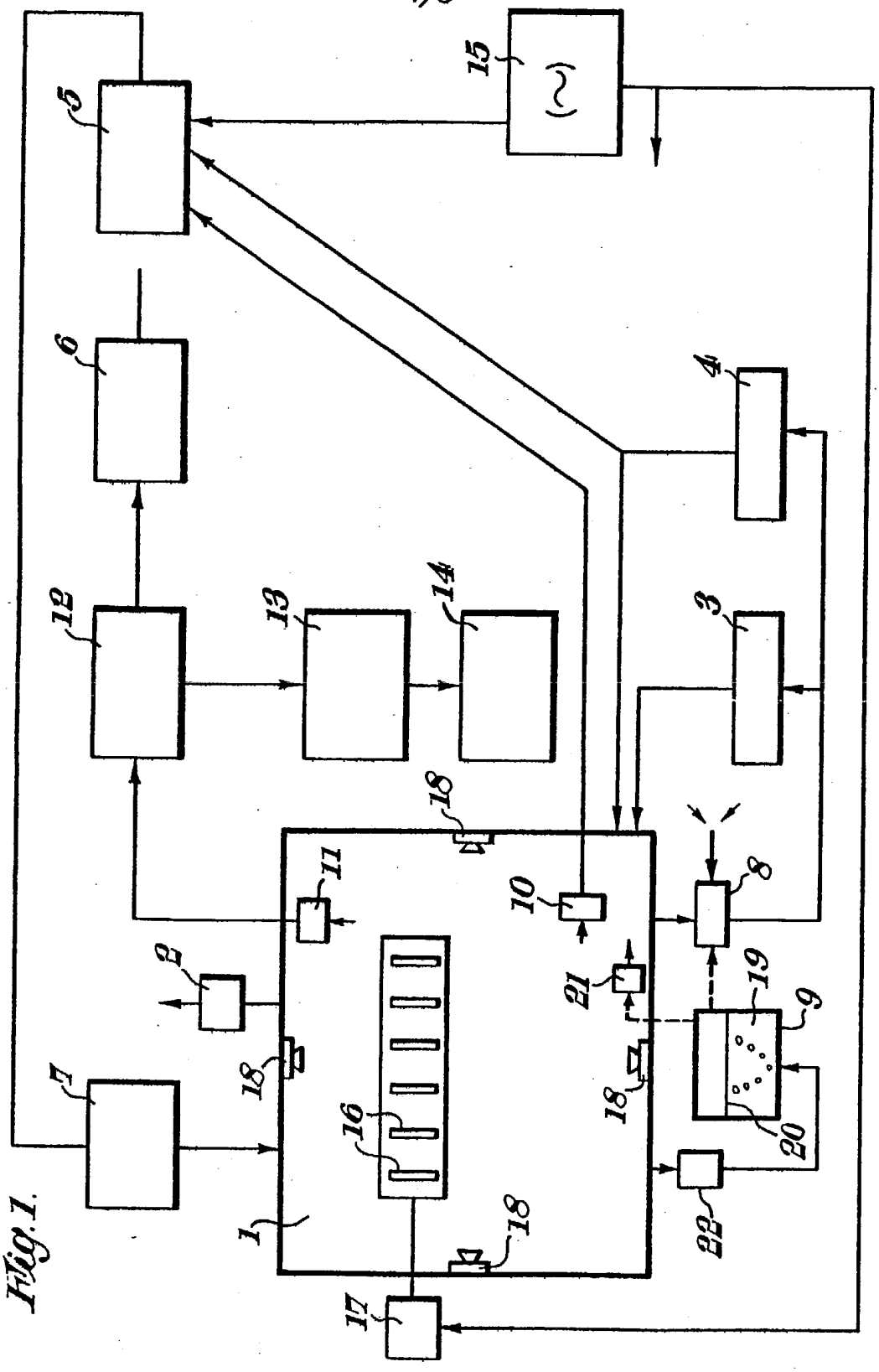
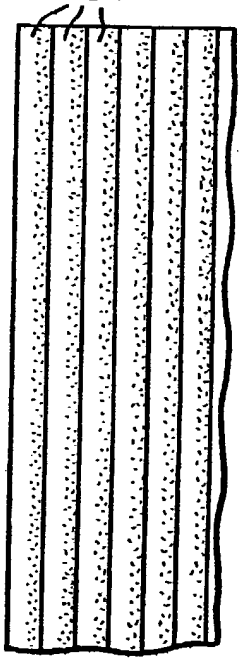


Fig. 1.

Fig. 2.



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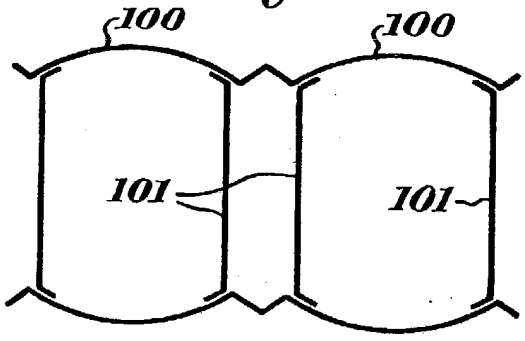
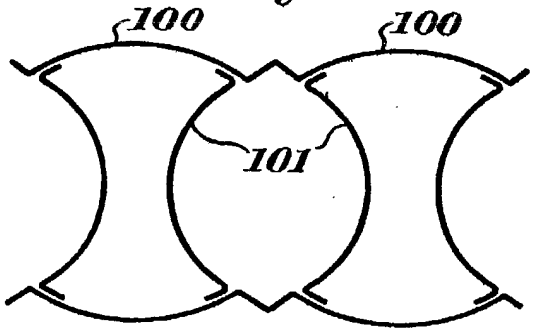


Fig. 4.



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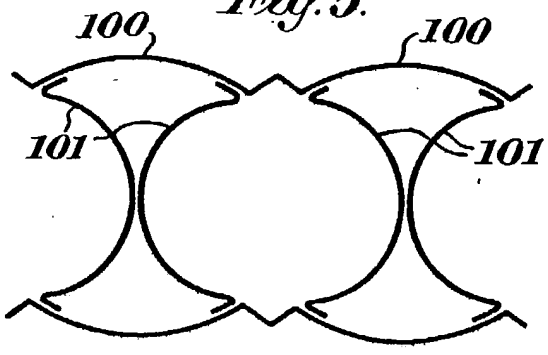

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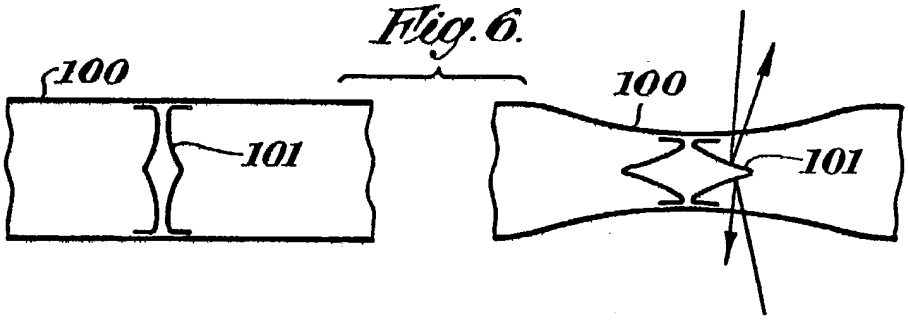


Fig. 7.

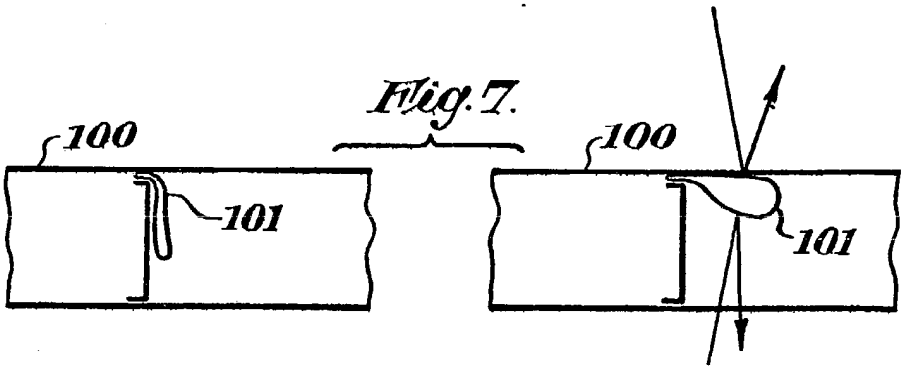
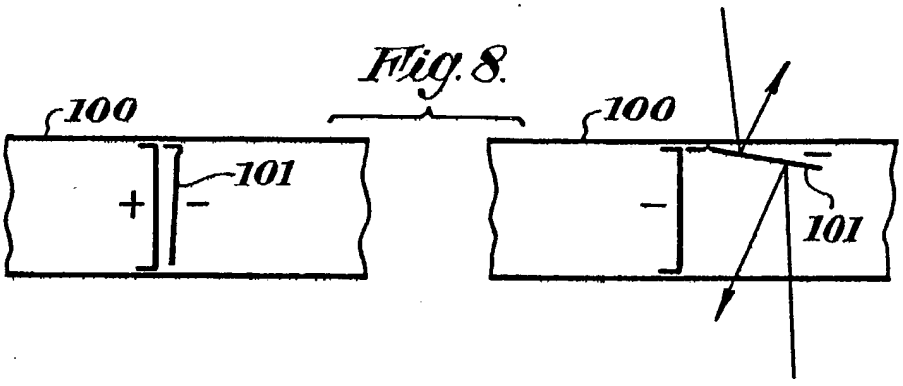


Fig. 8.



SPECIFICATION

Control of plant growing environment

This invention relates to a method and apparatus for controlling the growing environment of plants or the like.

In the growth of plants, photosynthesis is the process by which the energy of light is fixed by the chlorophyll of plants and used to build up the constituent element of saccharide formation from carbon dioxide and water. In previously proposed systems of controlling environmental conditions of plants, the plants are grown in light transmissive building structures i.e. greenhouse under various conditions of heat and light together with full facility for adequate ventilation. One reason ventilation is necessary is in order to enable the carbon dioxide in the plane environment to be renewed regularly. In normal atmosphere the amount of carbon dioxide is about 0.03% by volume. In the case of one kind of plant, cucumber, it has been found that if the carbon dioxide content of the atmosphere can be increased from 0.03% by volume to 0.13% at 20°C then the rate of photosynthesis can be more than doubled, if all of the light wanted or needed is supplied. If the temperature is then increased from 20°C to 30°C then the rate of photosynthesis is again more than doubled.

Such a controlled and graded increase in carbon dioxide in the atmosphere is, however, not possible with an open ventilation system. Furthermore, if an open ventilation system is not employed, there results an increase in humidity to a high level which is bad for plant health. This build-up in humidity arises partly through water coming out of a plant through "transpiration" 90% of which occurs through the stomata of the plant leaves and 10% of which takes place through the leaf surface.

Known examples of enclosed environment systems include those disclosed in U.K. patent specifications Nos. 1,349,001 and 1,147,025. However both specifications disclose systems in which only one or a few aspects of the environmental parameters are specified as being adequately controlled. The optimisation of plant growth is thus not made possible since, as is evident from an examination of the information available on the subject, it is important to ensure that a correct balance of environment parameters is provided if the improvements in some of the parameters is to have optimum effect.

According to one aspect of the present invention there is provided a method for controlling the growing environment of plants or the like characterised in that the method includes the steps of locating the plant or plants in an enclosed environment having no ventilation or only controlled ventilation via filtering means to external atmosphere, supplying carbon dioxide to said enclosed environment in excess of that normally contained in air at the temperature in the enclosed environment, detecting and adjusting the temperature and humidity of the enclosed environment, and providing a programme of duration, intensity and colour for the application of light to the enclosed environment to provide light conditions beneficial to plant growth.

According to a further aspect of the present invention, there is provided apparatus for controlling the growing environment of plants or the like characterised in that the apparatus includes an enclosure having no ventilation or only controlled ventilation via filtering means to external atmosphere, said enclosure defining a growing environment for plants, a carbon dioxide source for supplying carbon dioxide to said environment in excess of that normally contained in air at the temperature in the enclosed environment, means for detecting and adjusting the temperature and humidity of the environment, and lighting means controllable to provide a programme of duration, intensity and colour for the application of light to the environment to provide light conditions beneficial to plant growth.

This invention stems from the realisation that by providing a comprehensive degree of control of the environment parameters significant to plant growth, the latter can be optimised in a wide variety of geographical, climatic and weather conditions for a wide variety of plants. Thus apparatus and methods embodying this invention provide a versatility much needed in a world requiring increasing yields over increasing areas.

The otherwise accumulated oxygen in the atmosphere is used as a source of oxygen for combustion air for use in, for example, a paraffin burner which supplies carbon dioxide.

It is important to have an oxygen detection system in the combustion air supply line to either supply the combustion air from the enclosure or from the outside, whichever supplies the greater amount of oxygen in order to aid in the thorough combustion of paraffin to form carbon dioxide and not carbon monoxide which is toxic.

There may be occasions when the system would be used in combination with animal or human habitation as a source of oxygen for that habitation which may require an overriding control.

An embodiment of the invention will now be described with reference to the accompanying diagrammatic drawing in which:—

Fig. 1 is a schematic operational flow diagram of a system for controlling the growing environment of plants.

Fig. 2 is a schematic plan view of a part of a covering for a housing structure of the system whose operation is illustrated in Fig. 1;

Figs. 3 to 5 are respective cross-sections of a form of covering member used in the covering shown in Fig. 2 and illustrate three operative states of the covering member; and

Figs. 6 to 8 are similar views to Figs. 3 to 5 of modified forms of covering member the left and right hand sides of each figure showing different respective operative states of the covering members.

Referring to Fig. 1 of the drawings a building struc-

ture in the form of a close light-transmissive greenhouse or phytotron which may have no ventilation to the external atmosphere (i.e. closed cycle ventilation is used) and within which seeds and plants can be located for germination and/or growing purposes. In fact in the present embodiment filter controlled ventilation to the external atmosphere is provided via filter parts 2 (only one of which is shown). Located alternatively within or remote from the phytotron 1 are a plurality of burners 3, 4 of known type which effect rapid and complete combustion of paraffin as a fuel in order to produce supplies of carbon dioxide for supply to the plant environment within the phytotron. Burner 3 is arranged and utilised in known manner when it is desirable to feed both carbon dioxide and heat to the phytotron 1. In some cases, however, it may be desirable not to supply additional heat to the phytotron 1 but to supply only carbon dioxide. In this case burner 4 is used to supply carbon dioxide alone, the heat produced by the burner being transferred to a high temperature water heat sink 5. A medium temperature heat sink 6 is operatively associated with the high temperature heat sink 5 and heat can be supplied from the heat sink 6 to the environment *via* heat exchanger 7.

The combustion atmosphere for the burners 3, 4 is supplied by air selectively either from the external atmosphere of from the environment atmosphere within the phytotron. An oxygen detector and switching valve co-operate in a device 8 to select the supply air so as to provide the air having the greatest proportion of oxygen for combustion. The device 8 may also be connected (as shown in broken line) so as to obtain additional oxygen from an oxygen extractor 9 arranged to remove and store excess oxygen from the phytotron.

Temperature control within the phytotron is such as to maintain a temperature around 24½° C although variations will occur to provide a day/night cycle. Detectors 10, 11 control heat input and extraction from the phytotron for the purposes of temperature and humidity control.

It is desirable to maintain the humidity within the phytotron at or about 80% to 90% (depending upon which plants are grown) and in order to control the increase in humidity from rising substantially above this level, the phytotron is provided with cooling means whereby the temperature of the interior environment can be reduced to maintain humidity at the desired level. The cooling means includes a refrigerant which removes heat from the environment and feeds it to a refrigeration heat exchanger 12 which in turn supplies heat to store in the medium temperature heat sink 6, the cooled refrigerant being directed to low temperature cold sink 13 and medium temperature cold sink 14 which acts as sinks for heat from the environment.

Electricity for servicing the lighting and heating functions of the phytotron 1 is produced by, for example, a diesel engine generator 15 located remote from the phytotron 1 and the heat from the radiator and exhaust from the generator is re-cycled to provide a proportion of the heating required for the phytotron.

Within the phytotron 1 a lighting system is provided consisting of multiple banks of six fluorescent tubes 16 arranged parallel to each other. In each bank of tubes 16, the two outer tubes and the two innermost tubes are coloured a special controlled pink designed for suitable light emanation for chlorophyll, which pink colour contains red light which includes 660 millimicrons in wavelength but excludes 735 millimicrons in wavelength. The remaining two tubes are coloured blue. Separate control switches are provided for the pink tubes and the blue tubes so that they can be illuminated independently of each other or together.

Time clocks are provided for controlling the lighting system. Fluorescent lights are used because they are one of the most efficient forms of lighting in that 14% of electrical energy input is translated into light using 50 Hz A.C. electrical supply. A 10 KHz frequency converter can be incorporated in light control unit 17 to increase the efficiency by 11% and further imrovement in efficiency can be achieved by using krypton-filled fluorescent lights.

The function of the lighting system is to provide plants in the phytotron with the colours of light in the spectrum which the plant wants and needs for growth. Plants generally contain four types of chlorophyll namely A, B, C and D, the higher plants of the flowering type having chlorophyll A and B and lower plants such as bacteria and sea plants having chlorophyll C and D. The absorption spectrum varies in accordance with the types of chlorophyll present.

In operation of the lighting system, the controlling time clocks are set so that both pink and blue lights are switched on for a maximum light period of 16½ hours. If external illumination falls below about 1100 lux, supplementary illumination is turned on controlled by photocell with appropriate filters. After a 16½ hour period has terminated, a time period of 3 hours 45 mins. is allowed to lapse whereupon the pink lights only are illuminated. The pink light, which contains no far-red light, mainly 735 millimicrons is maintained at an intensity of at least 350 lux for about 25 minutes after which it is switched off to provide a dark period of 3 hours 45 mins. duration.

The types of time clocks employed are of the known design which take account automatically of variations in the time of sunrise and sunset.

The phytotron 1 can be provided along each side with heating apparatus for maintaining hot or cold each separate side as required, the heat being supplied or withdrawn by the closed heat sink arrangement described above.

Also the phytotron can be provided with sound producing apparatus 18 whereby sound can be created within the phytotron environment for selective absorption by the plants or at a frequency favoured by the plants as disclosed in U.S. patent specification No. 4,055,915.

From the above-described embodiment, it will be readily apparent that an enclosed system having only controlled or no (closed cycle) ventilation to external atmosphere is provided and in which (a) the supply of carbon dioxide, (b) temperature (c) humidity (d) light are carefully controlled to provide optimum conditions for the growth of plants or the germination of seeds.

Furthermore, the closed-cycle ventilation or filter-controlled ventilation results in absence of pollution and freedom from pollen, mould spores, moss spores, insects and dust. In the controlled ventilation, no air is allowed in to the environment without being filtered. Advantageously the pressure of the environment atmosphere is kept slightly above external atmospheric pressure so that any leakages which occur (as when personnel obtain access to and from the phytotron) give rise to an outward flow of air from the phytotron inhibiting ingress of impurities into the enclosed environment.

Although in the above described embodiment, banks of six fluorescent tubes are utilised, other arrangements of fluorescent tubes or other forms of lighting can be used. However the lighting arrangement must be capable of providing variation of duration, intensity and colour of the artificial light.

The extractor 9 can be arranged for passing air from the environment through a bubbling chamber 19 in which spent air is fed into water and through a silicone rubber membrane 20 to separate the carbon dioxide from the oxygen to allow the oxygen to be used for application to the plant root knees via pump 21 or other use as required (e.g. combustion). An oxygen detector 22 is provided to control (by extraction) the oxygen in the environment atmosphere so that it does not build up to too great an extent.

The phytotron can be provided with a covering capable of controlling radiation transmission through it. Such a covering is disclosed in U.K. patent specification No. 1,385,261. However a preferred form of covering is described below.

The preferred form of covering (unlike the covering disclosed in Specification No. 1,385,261) is suitable for providing a substantially fluid-tight seal between the external atmosphere and the enclosed environment. Also the preferred form of covering provides control of ingress and egress of light radiation into and from the enclosed environment.

Referring to Figs. 2 to 8, the preferring form of covering may comprise a plurality of inflatable tubular covering members 100 dielectrically welded or otherwise sealingly secured together. Each covering member 100 has partitions 101, which are reflective and adjustable in configuration by inflation (Figs. 3 to 7) or electrostatic means (Fig. 8) to control transmission of light through the covering in either direction.

Alternatively the covering may comprise a plurality of covering panels incorporating similar partitions 101. The covering panels may take any of the forms disclosed in West German Specification No. P 26 35 724.4.

The covering may have an opaque inner surface and a light transmissive outer surface. The light transmitted via the outer surface can be controlled by partitions such as the partitions 101 and incoming sunlight can be used to heat fluid passing between the inner and outer layers. The heated fluid can be used in various ways but may for example be used to supply a heat store.

CLAIMS

1. A method for controlling the growing environment of plants or the like characterised in that the method includes the steps of locating the plant or plants in an enclosed environment having no ventilation or only controlled ventilation via filtering means to external atmosphere, supplying carbon dioxide to said enclosed environment in excess of that normally contained in air at the temperature in the enclosed environment, detecting and adjusting the temperature and humidity of duration, intensity and colour for the application of light to the enclosed environment to provide light conditions beneficial to plant growth.

2. A method according to Claim 1 characterised in that heat supplied to or extracted from the enclosed environment is transferred via heat sinks associated with the closed environment.

3. A method according to Claim 1 or Claim 2 characterised in that said light is supplied cyclically as a mixture of pink and blue colour light for a first predetermined period and as pink light for a second predetermined period spaced by time intervals from said first periods of adjacent cycles.

4. A method according to Claim 3 characterised in that said pink light includes 660 millimicrons wavelength light and excludes 735 millimicrons wavelength light.

5. A method according to any one of the preceding Claims characterised in that oxygen is extracted from the enclosed environment.

6. A method according to Claim 5 characterised in that the oxygen is used to form at least some of the carbon dioxide supplied to the enclosed environment.

7. A method according to any one of the preceding Claims characterised in that the carbon dioxide is obtained by combustion of a carbonaceous fuel in an atmosphere containing oxygen.

8. A method according to Claim 7 as appendent to Claim 6 characterised in that the atmosphere containing oxygen is obtained selectively from the external atmosphere or from the enclosed environment in such a way as to optimise the oxygen content of the atmosphere for combustion.

9. A method according to Claim 7 or Claim 8 characterised in that heat produced as a result of said combustion is supplied to the enclosed environment.

10. A method according to any one of the preceding Claims characterised in that humidity in the enclosed environment is adjusted by extraction of heat from the environment.

11. A method according to any one of the preceding Claims characterised in that sound is applied to the plants at a frequency favoured by them.

12. A method according to any one of the preceding Claims characterised in that the atmosphere of the enclosed environment is kept at a pressure above that of the external atmosphere.

13. Apparatus for controlling the growing environment of plants or the like characterised in that the apparatus includes an enclosure having no ventilation or only controlled ventilation via filtering means to external atmosphere, said enclosure defining a growing environment for plants, a carbon dioxide source for supplying carbon dioxide to said environment in excess of that normally contained in air

at the temperature in the enclosed environment, means for detecting and adjusting the temperature and humidity of the environment, and lighting means controllable to provide a programme of duration, intensity and colour for the application of light to the environment to provide light conditions beneficial to plant growth.

14. Apparatus according to Claim 13 characterised in that heat sinks are arranged in selective thermal communication with the enclosed environment for storing heat extracted from the environment and for storing heat for supply to the environment.

15. Apparatus according to Claim 13 or Claim 14 characterised in that said light control means are arranged to supply light cyclically as a mixture of pink and blue colour light for a first predetermined period and as pink light for a second predetermined period spaced by time intervals from said first periods of adjacent cycles.

16. Apparatus according to Claim 15 characterised in that said pink light includes 660 millimicrons wavelength light and excludes 735 millimicrons wavelength light.

17. Apparatus according to Claim 15 or Claim 16 characterised in that fluorescent lights are provided for supplying light to the environment and means are provided for increasing the frequency of the A.C. electrical supply for the lights.

18. Apparatus according to any one of Claims 12 to 16 characterised in that means are provided for extracting oxygen from the enclosed environment.

19. Apparatus according to Claim 18 characterised in that means are provided for using the oxygen to form at least some of the carbon dioxide to be supplied to the environment.

20. Apparatus according to any one of Claims 13 to 19 characterised in that means are provided for burning a carbonaceous fuel in an atmosphere containing oxygen.

21. Apparatus according to Claim 20 as appendant to Claim 19 characterised in that means are provided for supplying oxygen to said atmosphere containing oxygen selectively either from the external atmosphere or from the enclosed environment in such a way as to optimise the oxygen content of the atmosphere for combustion.

22. Apparatus according to Claim 20 or Claim 21 characterised in that means are provided for supplying to the environment heat produced as a result of the combustion.

23. Apparatus according to any one of Claims 13 to 22 characterised in that heat transfer means are arranged for extracting heat from the environment to adjust humidity.

24. Apparatus according to any one of Claims 13 to 23 characterised in that the enclosure has a covering comprising light-transmissive inflatable covering members within which are arranged partitions which are reflective and adjustable in configuration to control light transmission through the covering in either direction.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1980.
Published at the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.